

LONG ARC SIMULATED LIGHTNING ATTACHMENT TESTING USING A 150 KW TESLA COIL

ROBERT K. GOLKA

Project Tesla, Wendover AFB, Utah 84083
 In conjunction with Air Force Flight Dynamics Laboratory,
 Wright-Patterson Air Force Base

Abstract

Recent advances in direct lightning strike testing have been in lightning attachment test techniques and generator development using a very large Tesla Coil (51 feet wide). Breakthroughs in simulated lightning attachment to small scale replica aircraft models which can be adapted to full size operational aircraft have been made in the past year. New high voltage long arc generator developments have succeeded in producing voltages in excess of 15 million volts and arc lengths in excess of 40 feet. The shortest path from the discharge arc electrode to the model extremity using the long arc does not govern the attachment points to the test specimen as it does when a short arc is used to conduct simulated lightning testing. The system just described may also have application as an ultra-high mega-volt source for particle beam weaponry.

model.

Background

At the present time the lightning susceptibility of aircraft is investigated using high voltage impulse generators. In a typical test involving streamering, the direct effects due to arcing are determined by discharging the generator in a localized area of an aircraft in such a manner that streamering is induced without arc attachment to the aircraft. The presence of streamering is indicative of a possible ignition source for combustible vapors. The procedure is repeated until total aircraft coverage is attained. Long arc attachment tests are conducted to verify the primary zones and to identify secondary attachment zones. For these tests the probe of a high voltage impulse generator is positioned to generate a long arc that attaches to the test specimen. The test is repeated a number of times with the probe at different orientations with respect to the test specimen to eliminate the possibility of biasing the attachment point and to simulate lightning flashes approaching from various directions. This is a time consuming procedure because of the set-up time and the charging time of impulse generators.

In contrast to the existing method, a Tesla Coil streamering test requires one set-up to identify the total streamering characteristics of a test specimen. Also, the high frequency nature of the Tesla Coil can generate many long arcs, of somewhat random lengths and paths (reducing test set-up bias).

Attachment Evaluation

The Advanced Design Composite Aircraft (ADCA) model used for the attachment evaluation was designed and built by Grumman Aerospace for the Advanced Composite Structures ADP, Structural Mechanics Division, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base. Lightning attachment tests to the ADCA model were subcontracted to Lightning Transient Research Institute (LTRI) initially. The

Introduction

The purpose of the program was to evaluate the Tesla Coil as a laboratory tool for lightning effects research on aircraft. The ability of a Tesla Coil to generate high voltage pulses at high rep rates results in the capability to create artificial lightning-like streamering and long electrical discharge arcs and makes it a desirable alternative to the high voltage impulse generators currently in use. Another characteristic of a Tesla Coil is that many long arcs can be generated over a very short time period. These Tesla Coil characteristics are highly desirable in lightning effects research using full scale (e.g. an actual aircraft) test specimens.

The primary objective of the program was to evaluate the Tesla Coil as a long arc source for lightning attachment studies. Secondary objectives of the program were to investigate methods for measuring the output characteristics of the Tesla Coil and the attachment characteristics of an Advanced Design Composite Aircraft (ADCA)

Report Documentation Page			Form Approved OMB No. 0704-0188	
<p>Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p>				
1. REPORT DATE JUN 1979	2. REPORT TYPE N/A	3. DATES COVERED -		
4. TITLE AND SUBTITLE Long Arc Simulated Lightning Attachment Testing Using A 150 Kw Tesla Coil			5a. CONTRACT NUMBER	
			5b. GRANT NUMBER	
			5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)			5d. PROJECT NUMBER	
			5e. TASK NUMBER	
			5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) USAF Flight Dynamics Laboratory, Atmospheric Electricity Hazards Group			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S)	
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited				
13. SUPPLEMENTARY NOTES See also ADM002371. 2013 IEEE Pulsed Power Conference, Digest of Technical Papers 1976-2013, and Abstracts of the 2013 IEEE International Conference on Plasma Science. Held in San Francisco, CA on 16-21 June 2013. U.S. Government or Federal Purpose Rights License.				
14. ABSTRACT Recent advances in direct lightning strike testing have been in:lightning attachment test techniques and generator development using a very large Tesla Coil (51 feet wide). Breakthroughs in simulated lightning attachment to small scale replica aircraft models which can be adapted to full size operational aircraft have been made in the past year. New high voltage long arc generator developments have succeeded in producing voltages in excess of 15 million volts and arc lengths in excess of 40 feet. The shortest path from the discharge arc electrode to the model extremity using the long arc does not govern the attachment points to the test specimen as it does when a short arc is used to conduct simulated lightning testing. The system just described may also have application as an ultra-high mega-volt source for particle beam weaponry.				
15. SUBJECT TERMS				
16. SECURITY CLASSIFICATION OF: a. REPORT b. ABSTRACT c. THIS PAGE unclassified unclassified unclassified			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 6
			19a. NAME OF RESPONSIBLE PERSON	

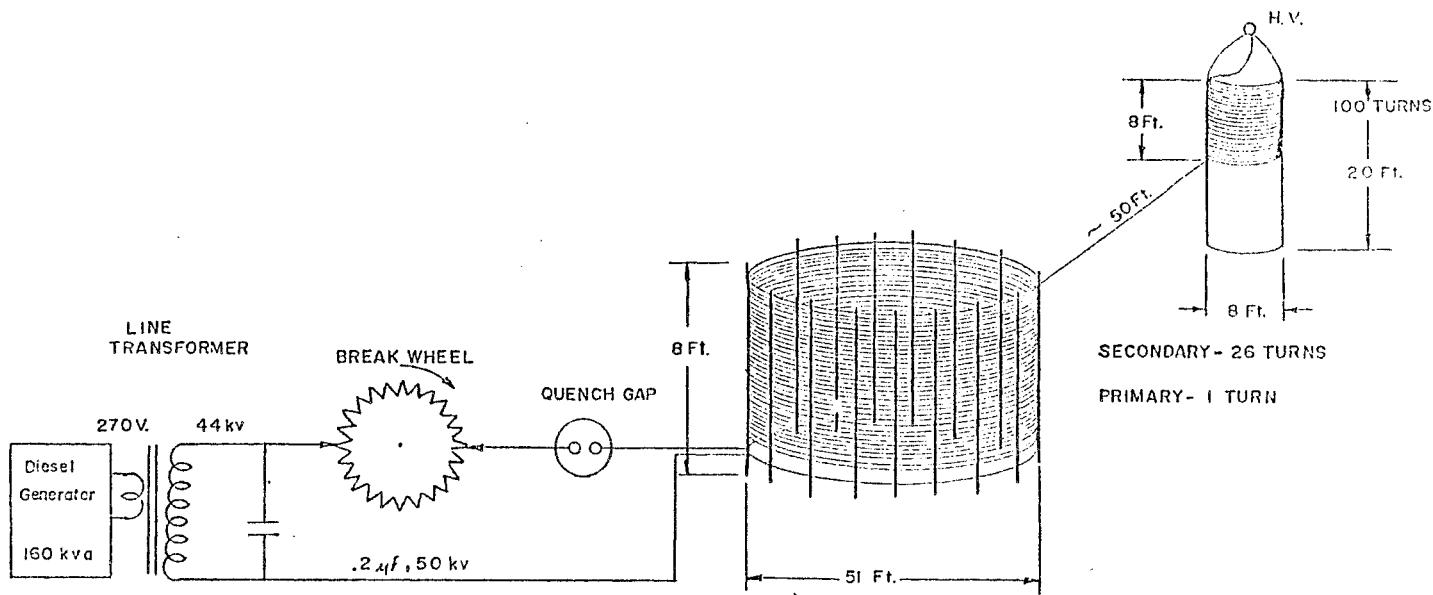


Fig I. Schematic Diagram of Golka Apparatus at Wendover

Electromagnetic Hazards Group obtained the model after the initial attachment tests. The model was taken to Wendover, Utah to the Associates 12 million volt Tesla Facility for further attachment studies. An F-4 model was also taken and used as a preliminary test set-up model.

The Tesla Coil test was conducted to evaluate its use as a long arc source for attachment studies. Data was taken with the model in three configurations and various positions. Data was obtained for comparison to that obtained during LTRI long arc attachment tests.

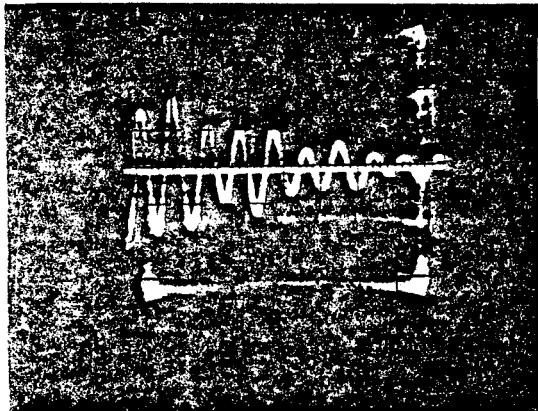


FIGURE 3: Typical Primary Circuit Current Measurement Using Pearson Current Transformer
Vertical Scale: 1200 Amps/Div.
Horizontal Scale: 200 us/Div.

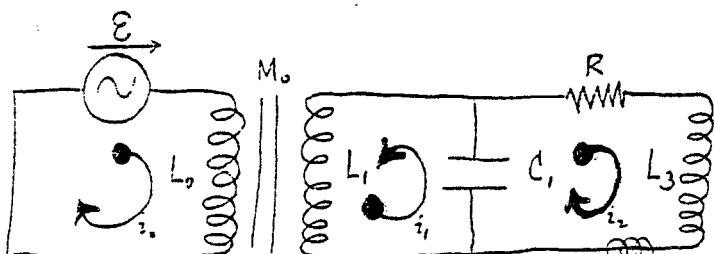
Measurement of Tesla Coil Characteristics

Some of the physical characteristics of the Tesla Coil that were of interest were the resonant frequencies of the primary and secondary circuits, the rise and decay times, commutation rate, and input current and output current values. The Tesla Coil circuit of Golka Associates is diagrammed in Figure 1 and its equivalent circuit is presented in Figure 2.

The current in the primary circuit was measured with a Pearson, model 301 current monitoring transformer (CT). A typical current measurement is depicted in the oscillosogram of Figure 3. The highest current measured was 3240 amperes.

The output voltage was determined to average about 10 megavolts. Higher voltages have been observed on different occasions, the highest being 25 megavolts. These measurements were made with capacitor divider techniques. The risetime of the output voltage was measured to be about 5 microseconds. The risetime of the output voltage is important to determine potential arc length. The risetime can affect voltage needed to break down a given air gap. 50 KC is the ringing frequency of the secondary/extra coil combination. 30 KC is the primary oscillatory frequency, the primary and secondary frequencies being pulled together somewhat due to high mutual coupling. This technique being used to prevent circulating currents between primary and secondary

Input Circuit



150 KW

L1=Primary of Power Transformer
L2=Secondary of Power Transformer
L3=Primary of Tesla Coil System

L4=Secondary of Tesla Coil System
L5=Extra Coil of Tesla Coil System

C1=Primary Circuit Charging Capacitor
C2=Distributed Capacitance of Extra Coil

TESLA COIL

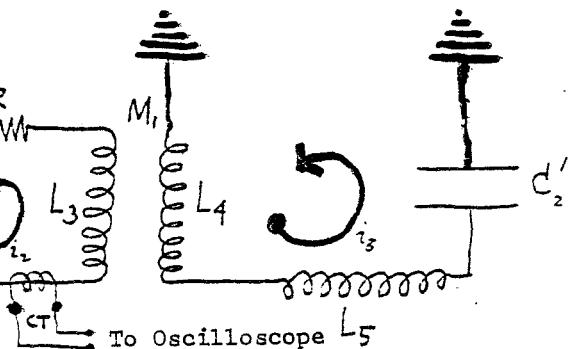
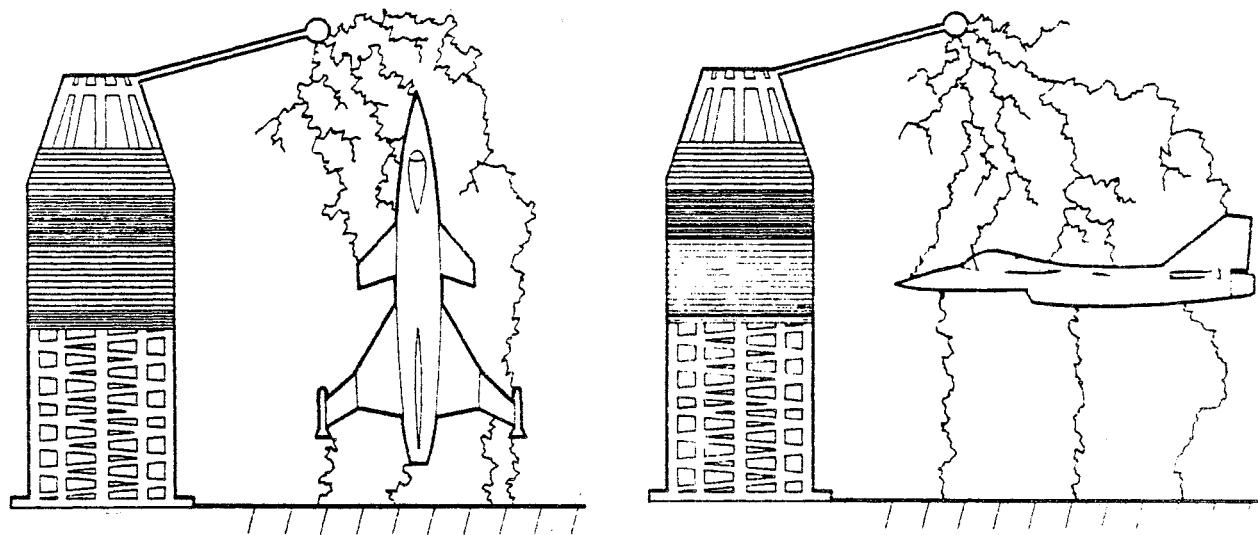
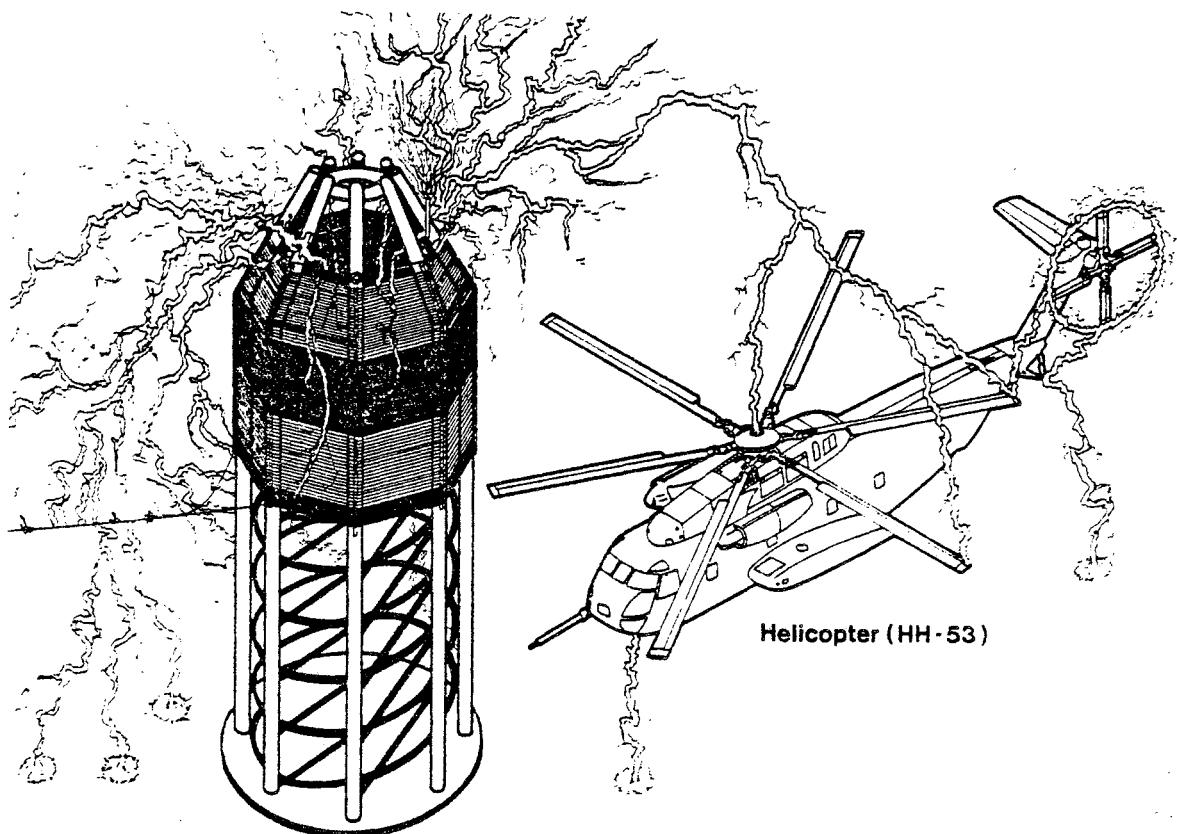


FIGURE 2: Equivalent Circuit of Golka Associates Tesla Coil



Various arrangements of models and full size aircraft along with electrode positioning and high discharge repetition rates (up to 4200 pulses per second) can now be achieved at this facility.



Golka TESLA Coil

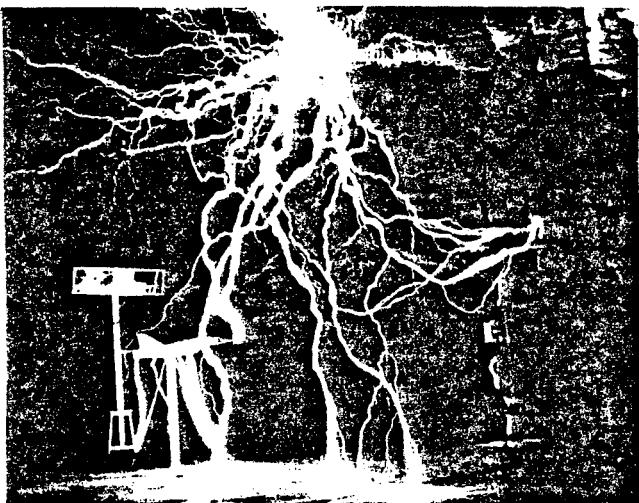
**Attachment Test
using TESLA Coil**

coils while maintaining tight coupling (.6 coupling coefficient). This prevents reignition of the quenching gap, which if reignited would generate an out of phase primary oscillation current which would beat with the secondary coil oscillating currents producing another output frequency current. This would lower the original oscillation voltage amplitude and of course broaden the spectral response. The mechanical analogy of this effect is the well known physics lab demonstration of two pendulums swinging on a common horizontal string, the driver transferring energy to the driven and the driven then transferring energy back to the driver.

During the attachment tests when the model was fairly near the discharge electrode and the Extra Coil, an arc attached to the canard and then swept up the aircraft to the nose. This phenomena can not be duplicated by Marx Generators. The reason for it appears to be due to the magnetic field sweeping the Extra Coil. The fields outside the coil near the center (half way up) loop outward, with the frequency of the output and the magnetic flux changing, the arc is being "pushed away" from the coil, thus protecting its insulation to a degree from corona and low current sparks. This may be an application for swept stroke testing and should be investigated.

Another possible application for large

scale Tesla Coil Systems is the likely possibility of using them as power supplies for ground based particle beam weaponry. The system can be made to supply hundreds of megavolts. Figure 4 is a schematic of a particle beam accelerator using a Large Scale Tesla Coil System.



Time Exposure Showing Multiple Arcs From Tesla Coil. Note the varied attachment points on the floor, accounting for varied voltage measurement on E-field sensors.

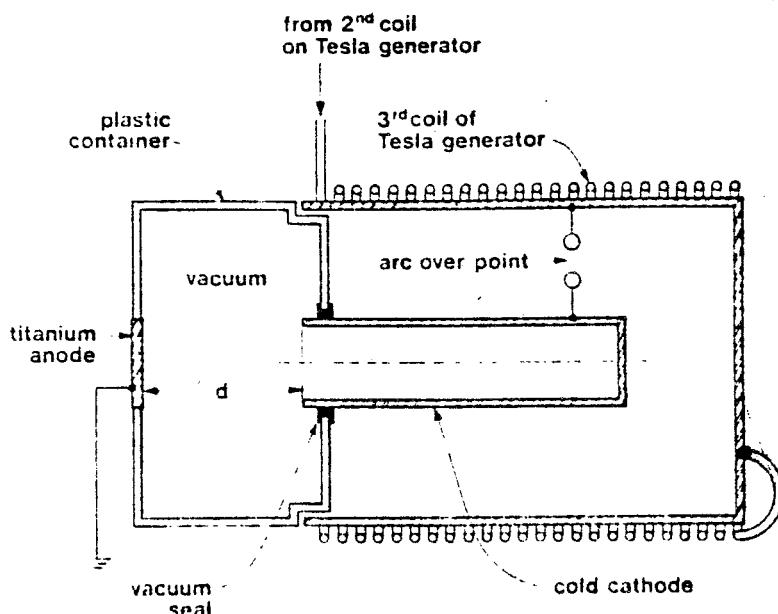


FIGURE 4: Schematic Of A Particle Beam Accelerator Using A Large Scale Tesla Coil System

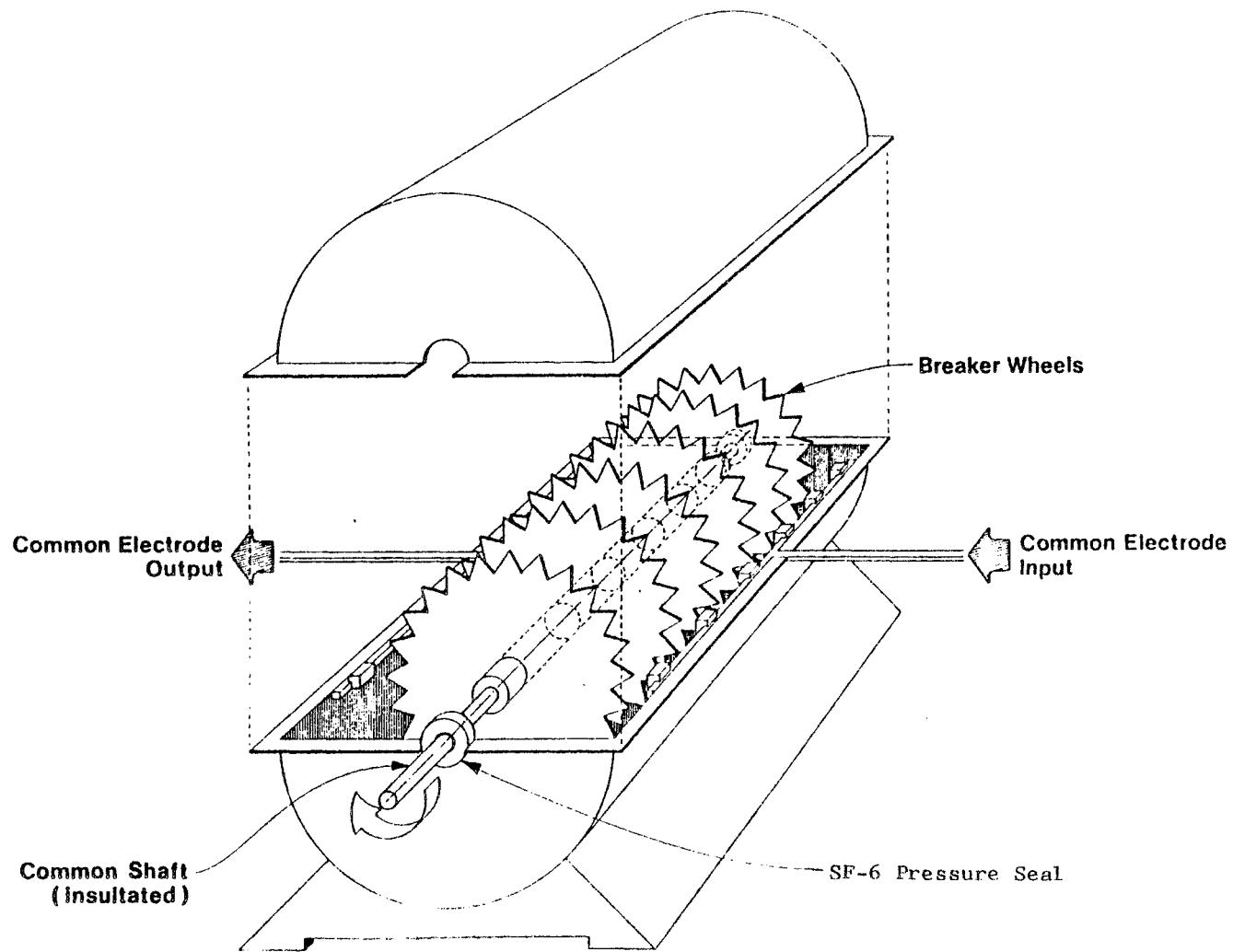


Figure 6. High Powered Ganged High Speed Switch Used with Large Scale Tesla Coil System for Powering Experimental Particle Beam Weapons